SILVA BALCANICA

Silva Balcanica 22(3): 29-39 (2021)
doi: 10.3897/silvabalcanica.22.e75511

RESEARCH ARTICLE

Green roofs – good regulatory practices with potential to be applied in Bulgaria and North Macedonia

Mariam Bozhilova[1], Miglena Zhiyanski[1], Biljana Stojanova[2], Plamen Glogov[1]

[1] *Forest Research Institute – Bulgarian Academy of Sciences, 132 St. Kliment Ohridski Blvd., Sofia 1756, Bulgaria*
[2] *Public Enterprise "Parks and Greenery", 104 Ilinden Blvd., Skopje, North Macedonia*

Corresponding author: Mariam Bozhilova (mariam@bozhilova.bg)

Academic editor: Ivaylo Velichkov | 20 September 2021 | Accepted 2 December 2021 | Published 16 December 2021

Citation: Bozhilova M., M. Zhiyanski, B. Stojanova, P. Glogov 2021. Green roofs – good regulatory practices with potential to be applied in Bulgaria and North Macedonia. Silva Balcanica 22(3): 29-39. https://doi.org/10.3897/silvabalcanica.22.e75511

Abstract
Green roofs are used worldwide to mitigate the impacts of extensive urbanization, bringing benefits on social, economic, and environmental levels. In order to promote and facilitate the construction of green roofs by private investors, many countries have developed specific legislative requirements and incentives. However, there still are countries where the construction of green roofs is not properly addressed in the legislation, and where no incentive mechanisms are developed.
The good practices in three European countries, leaders in regards to the implementation of green roofs – the Netherlands, Belgium, and Germany, are analyzed in this article. A variety of incentives is introduced to accelerate the construction of green roofs. Different requirements are also set to ensure that the roofs will be designed and maintained to provide the desired benefits. The existing local regulations in Bulgaria and North Macedonia were analyzed as well. The only incentive in Bulgaria is the possibility of reducing the legally required green area by compensating it with a green roof. In North Macedonia, no legislative documents or incentives related to green roofs were found.
The regulations, applied in the Netherlands, Belgium, Germany, and other countries can be used as good practice examples, modified, and applied from the authorities of countries that still have not developed their own, in order to motivate the investors and facilitate the construction of green roofs.

Keywords
best practice, green roofs, incentives, regulations

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Introduction

Green infrastructure is a successfully tested tool for providing ecological, economic, and social benefits through natural solutions (European Commission, 2013). Worldwide, it is increasingly used to mitigate the impacts of dense urban areas, contributing to the naturalization of the built environment (Liberalesso et al., 2020).

Roofs cover 21-25% of the hardened and unused urban areas (Wong et al., 2003). Nowadays they are not being exploited to their full potential and could be used to make cities more 'future proof' or resilient (Van der Meulen, 2014). Green roofs have a great potential to mitigate the impacts of extensive urbanization, bringing benefits on social, economic, and environmental levels (Teotonio et al., 2018). They have a good retrofitting potential and can be installed on old buildings (Wilkinson et al., 2009; Castleton et al., 2010; Naing, 2017). This provides the opportunity to reap the benefits of green infrastructure in highly urbanized areas that have no options for additional greening.

There are two main types of green roofs - extensive and intensive. In general, the extensive green roofs are with substrate depth up to 20 cm, minimal maintenance, low weight and low capital cost. Intensive green roofs are with substrate depth 10-100 cm, greater weight, higher maintenance requirements and higher capital costs. As a result of the increased substrate depth, the plants that can be used on intensive green roofs are more diverse (Peck, 1999; FLL, 2018).

Green roofs increase the albedo of urban areas and are a recognized tool for mitigation of the effect of urban heat islands (Kolokotsa et al., 2013; Saadatian et al., 2013). The albedo of a green roof varies from 0.7 to 0.85, while the albedo of bituminous, tar, and gravel roofs varies in the range 0.1–0.2 (Berardi et al., 2014).

Green roofs can help reduce urban air pollution. The annual absorption of pollutants in Chicago was found to be 85 kg/ha green roof /year (Yang et al. 2008). 52% of the removed pollutants constitute O_3, 27% - NO_2, 14% - PM_{10}, and 7% - SO_2. A green roof with the size of one square meter can compensate for the annual particulate matter emissions of one car (Rowe, 2011). Green roofs also contribute to minimizing CO concentrations (Li et al., 2010) as through photosynthesis, green roofs sequester CO_2. A survey of the carbon sequestration of green roofs with a substrate depth between 2.5 and 12.7 cm concluded that if all the roofs in Detroit Metropolitan area are covered with similar green roofs, plants and media could accumulate an amount of CO_2 equivalent to the emissions of approximately 10 000 mid-sized SUVs or trucks (Getter et al., 2009). Green roofs indirectly reduce the amount of CO_2 emitted by power plants and furnaces, thereby reducing the demand for heating and cooling and suggesting their long-term economic and environmental benefits (Li et al., 2014). An urban scale extrapolation of the estimated energy savings of typical multi-family buildings shows that after the installation of green roofs, there can be blocks in the city of Thessaloniki with reduced heating and cooling consumptions of up to 5% and 16% respectively (Theodoridou et al., 2017). Another study from Greece (Niachou et al., 2001) found that green roofs reduce the energy used for cooling by between 2% and 48% depending on the area covered by the green roof.

Green roofs can reduce noise pollution resulting from the road, rail, air traffic, etc., in urban areas (Van Renterghem et al., 2008, 2014). The substrate, plants, and the layer of air between the plants and the building surface serve as a sound insulator (Peck et al. 1999). Vegetation reduces the noise through reflection, scattering, and absorption (Wong et al. 2010; Van Renterghem et al., 2011). Noise reduction is observed not only in the building itself but also in the surrounding area. Green roofs, especially the sloped ones, contribute to the reduction of the noise of diffraction waves, which can enter a street without traffic, patios, etc. (Van Renterghem et al., 2008).

Green roofs effectively retain rainfall and delay the initiation of run-off from rainfall events. The main hydrological mechanisms during a rain event are the interception and retention of rain by vegetation, infiltration, and retention in the substrate and storage in the drainage layer (Kasmin et al., 2014). Understanding the hydrological performance of green roofs in different local weather conditions is the key to the successful implementation and development of sustainable practices to control run-off in urban areas (Najjar et al., 2020). The effectiveness of the green roofs varies in a very wide range (from 2 to over 70%) depending on the characteristics of the roof (type, slope, substrate, vegetation) and rainfall (Metselaar et al., 2012; Stovin et al., 2013, Feitos et al., 2015, Palla et al., 2010).

Green roofs also affect the chemical composition of rainwater run-off by absorbing some of the pollutants in and buffering acid rain (Teemusk et al., 2007; US GSA, 2011; Vijayaraghavan et al., 2012; Hashemis et al., 2015).

Due to their proven benefits in urban environment green roofs are getting increasingly popular worldwide. Many countries have developed specific legislative requirements and incentives to promote and facilitate the adoption of green roofs by private investors. Green roof policies applied around the world include programs that allow investors to build denser dwellings if a green roof is included, subsidies for building green roofs, mandatory greening of roofs on new buildings, tax incentives, reduction in different fees, etc.

Analysis of the policies used by municipalities to promote the installation of green roofs in 113 cities from 19 countries showed that financial subsidies and obligations by law are the most used ways to promote green infrastructure worldwide (Liberalesso et al., 2020). However, there are still countries where the construction of green roofs is not properly addressed in the legislation, although their potential is understood and green roofs are being constructed. Only 30% of the municipalities in Bulgaria have relevant ordinances, most of which set unreasonably high requirements. In North Macedonia analysis of the existing regulations showed that green roofs are not discussed in the relevant local or national legislative documents and are not subject to any incentives.

The good practices in three European countries, leaders in regards to the implementation of green roofs – the Netherlands, Belgium, and Germany, are analyzed in this article. The existing local regulations in Bulgarian municipalities were analyzed as well. The aim of the article is to identify possible ways for a wider implementation of green roofs in Bulgaria and North Macedonia through analyses of existing good practices and policies in the leading European countries.

Materials and methods

The existing local regulatory documents and the available incentives in selected municipalities from the Netherlands, Belgium, Germany, and Bulgaria are analyzed in this article. Five municipalities from each country were selected for the survey. The regulations of North Macedonia were also reviewed, however, no documents related to green roofs were found.

Results

Netherlands

In Amsterdam, a green roof is eligible for a subsidy if it is at least 30 m^2 and consists of a minimum of a root barrier, drainage, substrate, and vegetation layer. It needs to have a water storage capacity of at least 30 l/m^2. The roof has to be maintained for at least 5 years after receiving the subsidy. The costs are 50% eligible up to a maximum of 30 €/m^2 and 50 000 € for a green roof. The subsidy is 10 €/m^2 higher if more than 50% of it is covered with plants other than sedum and 20 €/m^2 higher if the roof's water storage capacity is more than 50 l/m^2 (Green roofs subsidy Amsterdam, 2021; Subsidy scheme Green in Amsterdam, 2021).

The city of Utrecht provides a subsidy for green roofs larger than 10 m^2. For intensive green roofs, the subsidy is 50% of the costs, no more than 50 €/m^2. For extensive green roofs, the subsidy is 50% of the costs, no more than 25 €/m^2. The total subsidy is a maximum of 20 000 € per application (Green roofs subsidy, City of Utrecht, 2021).

The city of Hengelo provides a subsidy for Green Roofs with an area of more than 6 m^2. A subsidy application can be submitted by owners, tenants, and owners' associations. The subsidy is 20 €/m^2 with a maximum of 2 000 € per address (Implementing regulation for granting subsidies green roofs, Hengelo, 2021). The green roof must at least consist of a root resistant layer, drainage layer, substrate layer, and vegetation layer. The water storage capacity must be at least 15 l/m^2 (General subsidy regulation, Hengelo, 2011).

The city of Leiden provides a subsidy for green roofs with an area of more than 15 m^2 (Green roofs subsidy, City of Leiden, 2021). It can be received by owners, tenants, leaseholders, owners' associations, and housing corporations. The subsidy is from 12 to 20 €/m^2, depending on the roof's area. The recipient of the subsidy has to maintain and preserve the green roof system for at least 5 years (General subsidy regulation of the municipality of Leiden, 2021).

The city of Arnhem provides a subsidy for green roofs with an area of more than 10 m^2 for residential buildings and more than 25 m^2 for office/commercial buildings. The subsidy varies between 30 and 65% of the costs, depending on the area where the building is located. It is higher in heat islands, places where flooding occurs, places sensitive to drought (Grant scheme initiatives for climate adaptation, City of Arnhem, 2016).

Belgium

The city of Brussels provides a subsidy for greening roofs as part of its Climate Plan (Brussels capital region energy-climate plan 2030, 2019). The roof has to be at least 2 m^2, the subsidy cannot be more than 3 500 € per building per period of 5 years. The subsidy is 20% higher if the roof is visible from at least 5 buildings.

In the Municipality of Merelbeke eligible for subsidy are roofs with an area of at least 6 m^2 green space. Individuals, companies, non-profit organizations, and associations can apply. The subsidy is up to 31 €/m^2 green roof with a maximum of 3 000 €. The municipality requires at least 15 years of maintenance of the roof. The construction has to meet the requirements of the Flemish Codex for Spatial Planning (Flemish Codex for Spatial Planning, 2009). The rainwater needs to be properly drained or transported to the sewerage system. The minimal requirements are that the roof has a drain layer, substrate layer, and vegetation layer (Green roofs subsidy, City of Merelbeke, 2021).

In Antwerp, the subsidy for the construction of a green roof is up to 15 €/m^2 for extensive green roofs and 30 €/m^2 for intensive green roofs. It can be for up to 65 m^2 per building. The subsidy covers as a maximum the total amount spent. The green roofs have to be maintained in good condition for at least 10 years (Green roofs subsidy, City of Merelbeke, 2021).

The municipality of Leuven provides a subsidy for the construction of green roofs according to the provisions of the Regulation on subsidy for rainwater installation, infiltration facility, and green roof (Regulation on subsidy for rainwater installation, infiltration facility and green roof, Leuven, 2020). The subsidy is 25 €/m^2 green roof with a maximum of 5 000 €. Only green roofs with a permanent character are eligible.

Extensive green roofs are eligible for a subsidy in Bornem. The subsidy can be up to 31 €/m^2, no more than 1 500 € per applicant. The roof needs to be maintained in good condition for at least 10 years. Applicants with an income of more than 28 730 € are not eligible for a subsidy (Green roof regulation, Bornem, 2014).

Germany

In Hamburg subsidy for green roofs is provided under the city's Green Roof Strategy (Green roof strategy, Hamburg, 2014). It applies for roofs with an area of more than 20 m^2, a slope up to 30°, and a substrate of more than 8 cm for existing and 12 cm for new buildings. Private owners with a 20 -100 m^2 green roof who live in the building receive a subsidy covering 40 - 60% of the total cost of the greening. Other owners receive an incentive ranging from 14 €/m^2 (for 8 cm substrate) to 56 €/m^2 (for 50 cm substrate).

The city of Bonn supports the development of green roofs with tax reduction incentives (Green the roofs of the city Bonn, 2018). Since January 1996 owners of green roofs can request a reduction in the precipitation fee, paid in Bonn. The reduction of the fee is calculated based on the roof's outflow factor, which depends on the vegeta-

tion and slope. For a roof with an outflow factor of 0.3 (substrate depth 15 cm, slope 15°) the precipitation fee will decrease by 20%.

All voluntary measures related to the greening of roofs are eligible for funding in Munich. Renovations of existing green roofs built before 1996 can also be funded. The subsidy for an extensive green roof with at least 8 cm substrate is 50% of the cost, but no more than 25 €/m^2. For intensive roofs, the subsidy is also 50% of the cost, but no more than 100 €/m^2 (Municipality of Munich, 2020).

In Essen all new buildings in the city with roofs with a slope up to 15° have to be greened at least extensively. The minimum thickness of the substrate has to be 6 cm and the greening has to be maintained permanently. This requirement is mandatory for 70% of the area of the roof, 30% may be used for renewable energy sources, technical facilities, daylight lighting elements, roof terraces, etc. Exceptions to the green roof requirement can be permitted only in case of an unreasonably high cost (Plan No 16/16, 20170).

In Bremen all flat roofs and roofs with a slope of up to 15° of new buildings, new parts of buildings, underground garages, and their covered driveways need to be greened unless otherwise stipulated by law. Flat roof areas of more than 100 m^2 have to be greened extensively and permanently. The total thickness of the substrate must be at least 10 cm (Greening local law, Bremen, 2019).

Bulgaria

In Sofia green roofs can be included in the total green area of a property in areas with building density over 60%, and in case the substrate depth is more than 60 cm. If the substrate is 30 - 60 cm, a multiplication factor of 0.8 is applied. Green roofs with a substrate less than 30 cm are not considered green area (Ordinance for construction, maintenance and protection of the green system of Sofia Municipality, 2007).

In Burgas in areas with a building density of over 60%, green roofs are included in the total green area of the property if the substrate layer is more than 60 cm. If the substrate layer is between 30 and 60 cm the area on the green roof is included in the green area of the property with a coefficient of 0.8. Green roofs with substrate 10-30 cm can be included in the green area only in case certified materials are used as a substrate. The coefficient, in this case, is 0.4 (Ordinance for construction, maintenance and protection of the green system of Burgas Municipality, 2008).

In Stara Zagora, green roofs are included in the total green area of the property if the substrate layer is 30 to 60 cm for shrubs and grasses and 80 cm for trees. In corner properties, where the maximum intensity and density of construction can be exceeded, mandatory greening of at least 10% of the terrain, roofs, walls, etc. is stipulated by the local legislation (Ordinance for construction, maintenance and protection of the green system of Stara Zagora Municipality, 2017).

In Pernik green roofs also need a substrate of minimum 60 cm to be included in the green area. All green roofs with a substrate depth below 60 cm are included in the area with a multiplication coefficient 0.3. A mandatory requirement for every green

roof in the municipality is to have an irrigation system (Ordinance for construction and protection of the green system of Pernik Municipality, 2014).

In Haskovo green roofs are included in the total green area of a property if the substrate is 60 cm or more. Green roofs with a substrate 30-60 cm are included in the green area with a multiplication factor of 0.8. Green roofs with a substrate less than 30 cm are not considered green areas (Ordinance for construction and protection of the green system of Haskovo Municipality, 2014).

Discussion

Green roofs have a great potential to mitigate the impacts of extensive urbanization, bringing benefits on social, economic, and environmental levels and are getting increasingly popular worldwide. Many countries have developed specific legislative requirements and incentives to promote and facilitate the adoption of green roofs by private investors. However, there still are countries where the construction of green roofs is not properly addressed in the legislation and no incentives are introduced.

In Bulgaria, only 30% of the municipalities have legislative documents relevant to green roofs. Most of them set unreasonably high requirements regarding the depth of the substrate and only green roofs with soil layer more than 60 cm are considered green areas with coefficient 1 (i.e. with 100% of their area). The only incentive in the country is the possibility to reduce the legally required green area by compensating it with a green roof. In North Macedonia green roofs are not discussed in the relevant local or national legislative documents and are not subject to any incentives.

The analysis of the good practices applied in three of the leading European countries in regards to the implementation of green roofs – the Netherlands, Belgium, and Germany showed that various incentives and mandatory requirements in regards to the green roofs are set in the local regulations. Part of the municipalities set minimum green roof area eligible for funding. It varies from 2 m^2 in Brussels to 30 m^2 in Amsterdam. In one municipality there is a differentiation between the minimum eligible area for residential and commercial/office buildings. Three municipalities included in the regulations list of mandatory components of the green roofs eligible for funding - root resistant layer, drainage layer, substrate layer, and vegetation layer. There are also requirements for minimum water storage capacity (e.g. 15 l/m^2, 30 l/m^2), and higher subsidy for roofs with a storage capacity of more than 50 l/m^2 (Amsterdam). Some municipalities require a certain period of maintenance of the green roof - from 5 years to permanent. There are also requirements for the minimum plant coverage, minimum depth of the substrate (e.g. 6 cm in Essen, 10 in Bremen), type of the green roof (in Bornem only extensive roofs are funded). The required depth may depend on the type of the building (e.g. the substrate thickness has to be more than 8 cm for existing and 12 cm for new buildings in Hamburg). In one municipality there is a requirement for rainwater to be properly drained or transported to the sewerage system. The subsidy provided varies between municipalities. Some municipalities pay a certain amount per square meter,

other - a percent of the amount spent. Many regulations include maximum funding. There is also a requirement for a maximum income of the owners, eligible for funding. The funding may depend on the plants that are being used, water capacity, location (e.g. to be higher in heat islands, places where flooding occurs, places sensitive to drought). In Brussels, the funding is higher if the roof is visible from at least 5 other buildings. The subsidy may depend on the substrate thickness, type of the roof, slope, ownership (private or not), etc. In two of the municipalities, the installation of green roofs is mandatory for new buildings with a slope up to 15°. In one municipality there is not a direct subsidy, but a reduction of the participation fee.

Conclusion

The executed analysis showed that there is a wide range of incentives already developed and applied, and conditions in regards to the construction and maintenance of green roofs in urban environment.

Countries and municipalities where green roofs are still not sufficiently addressed in the legislation may use them as a basis for developing requirements and incentives reflecting their specific needs.

The only incentive in Bulgaria is the possibility to reduce the legally required green area by compensating it with a green roof. In North Macedonia, no legislative documents or incentives related to green roofs were found.

The regulations, applied in the Netherlands, Belgium, Germany, and other countries can be used as good practice examples, modified, and applied from the authorities of countries that still have not developed their own, in order to motivate the investors and facilitate the construction of green roofs.

Acknowledgements

The study is part of the implementation of project within the framework of an approved action under the European Research and Technology Cooperation Program COST: CA17133 – Implementing nature based solutions for the creation of a resourceful circular city, Contract KP-06-KOCT/22 from 16.12.2019 „Green Infrastructure – Integration Opportunities on the Road to a Circular Economy, a Sustainable and Healthy Urban Environment“ funded by the National Science Fund – Ministry of Education and Science, Bulgaria.

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